Impediments to municipal water recycling in Australia

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IMPEDIMENTS TO MUNICIPAL WATER RECYCLING IN AUSTRALIA

S Khan, A Schäfer, P Sherman

Summary

Local authorities in Australia face twogreat challenges when managing municipal waters:

- Meeting future demands for clean water; and
- Preserving and enhancing the health of waterways.

Municipal water recycling provides a means to achieve these objectives by providing an alternative source of water as well as reducing sewage effluent discharges. This paper identifies the key factors impeding the rate of growth of water recycling in Australia. Such knowledge will be crucial to our effective allocation of efforts and resources required for a rapid and sustainable change in the way we manage our water. While Australia currently recycles around 11 per cent of effluents from sewage treatment plants, where is substantial scope for increase.

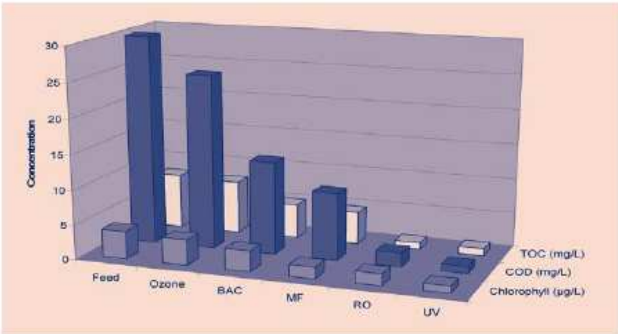

Figure 1. TOC, COD and chlorophyll concentrations after successive water treatment applications in the AWRDP (Khan *et al.*, 2003).

The key impediments are identified as:

- Lack of financial or economic incentive.
- Concerns regarding the effective destruction of pathogenic micro-organisms.
- Concerns regarding the presence of some inorganic and organic chemical contaminants.
- Costs, limitations and a lack of knowledge regarding the effectiveness of advanced water recycling technologies.
- Complications and costs associated with water transport and distributions systems.
- The need to ensure community acceptance.
- Energy demand and associated greenhouse gas emissions.
- Issues with storage systems for large volumes of recycled water.
- Availability of suitable reuse applications.
- Issues regarding national guidelines and standards.

Each of these issues will be addressed in a contemporary Australian context. Many of the identified constraints are of a practical nature and will require engineering-type solutions. Others are institutional and relate to current public policies, authorities and regulations. Having identified the impediments, the next task is to investigate ways to address them. An effective means of achieving this is promoted through a multidisciplined, integrated approach to research and management of the total water cycle. This approach should facilitate scientists, engineers, planning authorities, policymakers and regulators to find sound, workable solutions, thereby ensuring a sustainable future for water management in Australia.

Introduction

Current estimations are that Perth will require new water sources by between 2005-2007; Brisbane by 2015; Canberra by around 2017; and Melbourne by 2040 (Senate Environment Communications Information Technology and the Arts References Committee, 2002). This is at a time of strong opposition to new dams and extractions, along with rapidly growing support for replenished environmental flow regimes to many natural systems. Furthermore, increasingly stringent environmental regulation is rendering the practice of sewage discharge difficult to sustain. Discharge requires detailed and careful consideration of the full environmental impacts. Contemporary environmental legislation maintains that discharge is not a favourable option for sewage effluent and should only be considered once all other possibilities have been rejected. The most plausible approach to longterm sustainability of Australian water resources involves the treatment and subsequent reuse of municipal sewage. In addition to conserving or supplementing fresh water supplies, recycling offers an environmentally sound alternative to effluent discharge. During the 1990s, Australian towns and cities began experimenting with small-scale water reuse programs. A national average of 11% of the effluent from sewage treatment plants was allocated for reuse during 2000 (CSIRO, 2002). Of this, around 32% was used in the mining industry and 28% in agriculture. Much of the remainder was used to irrigate parks and sports grounds. Recycled water in some areas, such as Rouse Hill (NSW), Newington (NSW) and New Haven Village (SA), is redistributed to households for limited use via dual reticulation supply systems. However, such projects are exceptional and account for only a very small portion of total water use in Australia. There are now strong moves to embrace water recycling as a major component of demand management strategies for all major cities within Australia. For example, the Victorian Government has announced a water reuse target in Melbourne of 20% by 2010 and the West Australian government has committed to a 20% reuse target for Perth by 2012. In Brisbane, water recycling is promoted largely as a means of reducing point source discharges and improving water quality in Moreton Bay. However, before large-scale, viable and sustainable water recycling can become a reality, there is evidence that Australia must overcome some technological and institutional constraints. These constraints are outlined herein and indicate areas where further research efforts are urgently required.

Financial and Economic Incentive

A major obstacle to widespread water reuse in Australia has been the historic undervaluing and under-pricing of fresh water supplies. The small financial costs incurred by the use and disposal of fresh water supplies have provided little marketforce incentive for water recycling applications. At present, municipal water around Australia generally costs less than $1 per kilolitre to the consumer. The low cost stems from the lack of requirement to include catchment management and protection of effluent-receiving environments in current pricing regimes. In many cases, the consumer also pays sewerage charges that include the cost of treatment to a standard that is acceptable for discharge to the environment. These are separately accounted for and not integrated with the costs associated with producing and delivering potable water. The cost of producing and delivering recycled water is, in almost all current circumstances, greater than the costs for fresh water. However, users are uniformly charged less for recycled water than for fresh water due it its more limited use. A more transparent "whole of water cycle management" costing and pricing system would provide more appropriate price signals and incentives to consumers. Addressing this issue of incentive through changes in water-pricing structures would not be a simple task, and the cost of municipal water usage is potentially highly contentious. Since good-quality water is a basic human requirement, it is essential that some quantity remains highly affordable to all. Further controversy could arise over pricing for large commercial users including farmers. This is illustrated by recent comments by the Federal Minister for Agriculture, who expressed concern for proposals "...based on the idea that farmers should pay more for water and be compensated by Australians paying more for homegrown food. Why would Australian consumers pay more for homegrown food [he asked] when imported products grown with free water could be so much cheaper?" (Truss, 2003).

Pathogenic Organisms

A survey undertaken in Queensland indicated that public health and environmental issues associated with microorganisms were of greatest concern to current and prospective users of recycled waters (Higgins *et al*., 2002). Pathogenic organisms, known to be present in raw municipal sewages, include helminths, viruses, bacteria and parasitic protozoa. Infectious *Cryptosporidium parvum* oocysts were recently reported in 40% of final disinfected effluents from six water recycling facilities in the USA (Gennaccaro *et al*., 2003). However, the concentrations reported were extremely low and comparable to many natural water sources. Of the range of microorganisms known to be present, enteric viruses are considered to have the greatest potential to spread through the reuse of treated sewage (Fane *et al*., 2002). The high numbers excreted by infected individuals and the difficulties associated with physical removal are both primary contributors to the dissemination of these organisms. Therefore, contact with treated sewage through increased rates of water recycling will always involve some increased risk of waterborne disease. A compounding factor is the lack of knowledge about the survival of viruses in the environment or their susceptibility to disinfectants. In addition, analytical techniques have limitations that prevent the accurate enumeration of viruses in water. Furthermore, when we do detect viruses in water, we do not know what levels will cause infection or disease. Consequently, risk assessment approaches are limited.

Inorganic and Organic Chemical Contaminants

Sewage effluents typically carry significant loads of inorganic and organic chemicals, many of which are not removed during conventional biological treatment processes. In some cases, it is unknown whether some substances are removed during treatment or if the level of reduction is sufficient to prevent impacts. Inorganic salts such as sodium chloride and a suite of trace elements including heavy metals may be introduced to irrigated pastures and associated waterways via recycled water. In dry climates, much of the irrigation water evaporates and the concentration of salts in the drainage can be much higher than in the water itself, posing potential threats to groundwater quality (Bouwer, 2000). Salinity is already a major environmental problem in many parts of Australia and no water management program can afford to exacerbate it in this way. During the last decade, questions have been raised regarding the effects of dilute organic chemical contaminants in recycled water. Factors contributing to the observed persistence of some compounds in sewage effluents include typically high water solubility and, in some cases, a resistance to aerobic biodegradation. An increasingly documented class of trace organic contaminants in water are the "endocrine disrupting chemicals". Much attention has been devoted to natural and synthetic steroidal hormones, which are shown to induce biological effects on some organisms at part per trillion concentrations. Some steroidal hormones are poorly removed in conventional water treatment processes. Other chemicals exhibiting similar effects and known to be present in sewages include some plasticisers, pesticides and degradation products of some detergents. The presence and implications of endocrine disrupters in sewage and the environment has been discussed from an Australian perspective (Ying & Kookana, 2002). Further widespread attention has been given to the broad range of pharmaceutically active compounds which have been reported in municipal wastewaters in many parts of the world (Andreozzi *et al*., 2003, Huggett *et al*., 2003). Studies undertaken in Australia have identified a range of analgesic, antiinflammatory, anticonvulsant, antihypertensive, antiopiate, lipidregulating and even illicit drugs in municipal sewage (Khan & Ongerth, 2003). No direct public health implications of these compounds in recycled water have been proven. However, the current concerns are considered justified because potential effects of ingestion or agricultural application of these complex, low concentration mixtures remain largely unknown. There exists a huge array of biologically active compounds, many more of which have not been individually identified, but are likely to be present (Khan & Ongerth, 2004). Recent attention in the USA has been given to the detection of the potent carcinogen, nitrosodimethylamine (NDMA). NDMA has been reported in chlorinated sewages intended for reuse and is believed to be formed as a by-product of the disinfection process (Mitch & Sedlak, 2002). The formation of this substance may limit the form of disinfection applied to recycled water. Importantly, many of the key chemicals of current concern in sewage effluents were unknown or barely considered a decade ago. Their increased rates of detection reflect rapid advances in analytical capabilities rather than significantly increased concentrations of most compounds. It is therefore likely that new compounds will continue to be identified and the authors believe that a complete chemical understanding of water intended for reuse is not currently realistic.

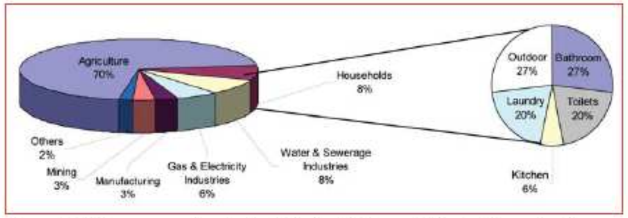

Figure 2. Water consumption in Australia by industry and (Sydney) households. Compiled from data from Australian Bureau of Statistics (2000) and Sydney Water (1999).

Advanced Water Recycling Technology

Advanced water recycling technologies have varied potentials and limitations in the treatment and removal of biological and chemical contaminants in water intended for reuse. Potential threats to groundwater quality (Bouwer, 2000). Salinity is already a major environmental problem in many parts of Australia and no water management program can afford to exacerbate it in this way. During the last decade, questions have been raised regarding the effects of dilute organic chemical contaminants in recycled water. Factors contributing to the observed persistence of some compounds in sewage effluents include typically high water solubility and, in some cases, a resistance to aerobic biodegradation. An increasingly documented class of trace organic contaminants in water are the "endocrine disrupting chemicals". Much attention has been devoted to natural and synthetic steroidal hormones, which are shown to induce biological effects on some organisms at part per trillion concentrations. Some steroidal hormones are poorly removed in conventional water treatment processes. Other chemicals exhibiting similar effects and known to be present in sewages include some plasticisers, pesticides and degradation products of some detergents. The presence and implications of endocrine disrupters in sewage and the environment has been discussed from an Australian perspective (Ying & Kookana, 2002). Further widespread attention has been given to the broad range of pharmaceutically active compounds which have been reported in municipal wastewaters in many parts of the world (Andreozzi *et al*., 2003, Huggett *et al*., 2003). Studies undertaken in Australia have identified a range of analgesic, antiinflammatory, anticonvulsant, antihypertensive, antiopiate, lipidregulating and even illicit drugs in municipal sewage (Khan & Ongerth, 2003). No direct public health implications of these compounds in recycled water have been proven. However, the current concerns are considered justified because potential effects of ingestion or agricultural application of these complex, low concentration mixtures remain largely unknown. There exists a huge array of biologically active compounds, many more of which have not been individually identified, but are likely to be present (Khan & Ongerth, 2004). Recent attention in the USA has been given to the detection of the potent carcinogen, nitrosodimethylamine (NDMA). NDMA has been reported in chlorinated sewages intended for reuse and is believed to be formed as a by-product of the disinfection process (Mitch & Sedlak, 2002). The formation of this substance may limit the form of disinfection applied to recycled water. Importantly, many of the key chemicals of current concern in sewage effluents were unknown or barely considered a decade ago. Their increased rates of detection reflect rapid advances in analytical capabilities rather than significantly increased concentrations of most compounds. It is therefore likely that new compounds will continue to be identified and the authors believe that a complete chemical understanding of water intended for reuse is not currently realistic.

Advanced Water Recycling Technology

Advanced water recycling technologies have varied potentials and limitations in the treatment and removal of biological and chemical contaminants in water intended for reuse. manner in which it is to be distributed. For example, guidelines in NSW restrict recycled water from uses including showers, clothes washing and swimming pools (NSW Recycled Water Coordination Committee, 1993). Consequently, dual reticulation water supply systems, comprising dedicated pipes, taps and fittings, are necessary. Further infrastructure costs and barriers to the retrofitting of established plumbing may result. Dual reticulation systems also require additional on-going management to prevent potential cross-connections with potable water systems (de Rooy & Engelbrecht, 2003). Further concerns associated with distribution systems for recycled water arise from the increased potential for biofilm growth in pipelines (Higgins *et al*., 2002). Biolfilms can dissipate disinfection residuals, alter water quality and potentially support the growth of pathogenic bacteria. The first and largest dual-reticulation scheme in Australia was established at Rouse Hill in NSW. The cost of supplying recycled water to the homes in Rouse Hill remains heavily subsidised in order to favourably compete with the available potable water supply. This has rendered the cost-effectiveness of the scheme questionable (Law, 1996). A newer recycling and dual-reticulation system is operated by the Sydney Olympic Park Authority at Newington. The construction and operation of this scheme was subsidised by the NSW Government as a demonstration project. However, further comparable projects will rely on cost reductions or changes in pricing policy for their economic viability (Senate Environment Communications Information Technology and the Arts References Committee, 2002). Although the greatest volumes of sewage are generated in the major cities, the greatest water demand is typically in agricultural areas. The need to transport recycled waters long distances requires additional major infrastructure, which adds significantly to the cost. The most substantial piece of infrastructure for the transport of recycled water is currently the Virginia Pipeline in South Australia (Kracman *et al*., 2001). Since 1999, recycled water from Adelaide's largest water treatment plant has been delivered via the pipeline to agricultural areas in Northern Adelaide and the Barossa Valley. A similar scheme has been initiated to deliver water from Hobart to the Coal River Valley in Tasmania (McIntyre, 2003). However, a proposal for a pipeline from Brisbane to supply recycled water to the Lockyer Valley and Darling Downs (QLD) has been shelved since the release of a report questioning the schemes financial viability (South East Queensland Recycled Water Task Force, 2003). The cost of supplying the water over such a distance was estimated at up to $1000 per ML, well above the $150 per ML offered by the potential end users. Local and state governments may partially overcome the need for long distance water transport by encouraging water thirsty industries to locate around the alternative source of water. One proposal suggests that flower nurseries could be clustered around sewage treatment plants.

Community Acceptance

A recent study has indicated strong community support (99%) among Australians for water reuse for applications such as watering lawns and gardens (McKay & Hurlimann, 2003). However, this support drops off sharply as the intended uses become more personal. Only moderate support was reported for clothes washing (49%) and less than 1% support for the supplementation of drinking water. A survey of Australian households currently connected to dual reticulation systems indicated a belief that recycled water should cost less than potable water and that very few would be willing to pay more for water as a conservation measure (Marks *et al*., 2003). Community concerns will significantly impact on the way water is ultimately recycled in Australia, as they have in other countries. In the USA, lack of public acceptance of potable reuse has resulted in the abandonment of a number of major water recycling schemes in cities such as Denver, San Diego and Tampa (DeSena, 1999, Okun, 2002). Already in Australia, a lack of community acceptance has prevented an indirect potable reuse scheme from proceeding in Caboolture, Queensland during the 1990s. The political fallout attributed to this incident has bred reluctance among other governing bodies to make policy statements on water recycling without assurances of community support (Gibson &

Apostolidis, 2001). Effective water awareness and educational programs are needed to build and maintain broad community support for potential water recycling programs.

Energy Demand and Greenhouse Gas Emissions

More stringent treatment requirements for what is currently deemed wastewater may require significant increases in energy use and associated emissions of carbon dioxide. Many of the most promising advanced water treatment technologies including advanced oxidation and membrane filtration processes are highly energy intensive. Accordingly, it has been estimated that Melbourne's 20% recycling target could result in the production of 28,000 tonnes of carbon dioxide (Fisher, 2003). Secondary treatment of wastewater produces considerable quantities of combustible "biogases". These gases may be more efficiently harnessed and utilised to off-set the increased energy requirements. Some major components of biogases are also greenhouse gasses, for example methane. Therefore combustion of biogases, while still producing carbon dioxide, may result in less net-greenhouse gas production than would result from not harnessing the biogas and producing energy from elsewhere. The need to transport recycled water over large distances will require further energy input and result in further greenhouse gas emissions. These issues were cited as key obstacles leading to the recent abandonment of a major proposed water recycling scheme in South East Queensland (South East Queensland Recycled Water Task Force, 2003). In some circumstances however, there may be energy offsets due to the reduced requirement to treat and pump fresh water supplies. Effective means of energy accounting need to be developed to consider these factors appropriately.

Storage Systems

In order to effectively recycle large volumes of water, considerable water storage capacity will commonly be necessary. This is often particularly the case in agricultural reuse schemes where the demand for water may be highly seasonal. If the recycled water is to be kept isolated from fresh water supplies, new segregated storage solutions will be required. The CSIRO have conducted extensive research into the use of aquifers to store recycled water in South Australia (Dillon *et al*., 1999). Advantages of such schemes include enhanced microbial die-off and the minimisation of loss by evaporation. While the process is highly promising, a number of obstacles remain to be overcome. Clogging of the aquifers and the need to ensure protection of native groundwater and geochemistry are among the concerns. Australian guidelines on the quality of treated wastewater intended for aquifer storage and recovery (ASR) largely neglect the issue of trace organics, and a lack of relevant knowledge is recognised (Dillon & Pavelic, 1996). However, preliminary indications suggest that some key organics, including some pharmaceuticals (Khan & Rorije, 2002) and endocrine disrupters (Ying *et al*., 2003) may largely survive the aquifer storage processes.

Reuse Applications

The ability to identify suitable applications for the use of new recycled water in Australia will be crucial to its success. Although households account for only around 8% of water consumption, there remains significant potential demand for recycled water in urban areas. For example, the 4 million residents of Sydney consumed around 1.8 GL per day of potable water during 2002. Of this, it is estimated that only around 6% was used for consumption and food preparation as shown in Figure 2 (Sydney Water, 1999). This presents an opportunity for reuse applications as a substitute for much of the remaining potable water consumed. Also shown in Figure 2, agricultural industries are by far the largest consumers of water, (Australian Bureau of Statistics, 2000). Substitution by recycled water for current agricultural applications will result in more water being available for critical potable applications and to maintain the health of rivers and waterways. There is also significant potential to achieve substitution of recycled water for current industrial applications that consume potable water. An example is the Illawarra Wastewater Strategy which is currently under construction (Sydney Water, 2003). When completed, this project will deliver 20 ML/day of recycled water from the upgraded Wollongong Sewage Treatment Plant for use by the BlueScope

Steel manufacturing plant. This will replace industrial use of potable water currently supplied from the Avon Dam. However, suitable users of large volumes of recycled water are not always immediately forthcoming. An example highlighting potential difficulties is the South Boulder (WA) water recycling plant. This plant began operation in 2002, however the town council had yet to establish a market for the surplus effluent a year later and highly treated water was going to waste. At that time the city engineering services director was quoted in the local press as stating "if we are lucky enough to find a market for all the effluent we could break even but at this stage it is like similar plants and is being funded by sewage rates" (Tasker, 2003). This situation is for an isolated town, with considerable mining activity, in a very dry region of Western Australia.

National Guidelines and Standards

In 1994 the Council of Australian Governments initiated the National Water Reform Framework for the management and use of water across Australia. However, at the time, water recycling measures were not included. More recently, federal and state governments have agreed to pursue possibilities for broadening the Framework to include water recycling in urban areas. An anticipated outcome is the "National Guidelines on Water Recycling: Managing Health and Environmental Risks", the first stage of which is not expected to be completed until December 2004 (NRMMC, 2003). The existing principal source of standards in Australia is the guideline for the use of reclaimed water prepared by the National Water Quality Management Strategy (2000). While this document provides guidelines for a national approach, State governments currently develop their own complimentary rulings. These are not enforceable standards, however, and reuse schemes still require approval of local health authorities and local government (Mitchell *et al*., 1999). National guidelines and standards based on appropriate system management criteria are urgently needed to complement guidelines on quality requirement for particular applications. System management criteria would include guidelines on community consultation, system design, risk management, operation and maintenance, monitoring and communication related to both treatment and distribution systems. Until such national guidelines and water quality standards exist, long term planning and development of reuse schemes will remain hindered. The lack of definite system management criteria and the current singular focus on water quality parameters will be a deterrent to many potential users and suppliers of recycled water who are cautious of legal implications.

Conclusion and Recommendations

The urgent need for widespread municipal water recycling in Australia has been established. While the uptake has increased over the last decade, there remains considerable scope for new and expanded sustainable recycling applications that will result in improved sustainable water use efficiency. A broad range of scientific, engineering and institutional impediments have been identified here as factors limiting further progress. To overcome the identified obstacles, a dedicated commitment to excellent science and engineering, backed by strong and sometimes challenging policy will be required. This identification of impediments to water recycling highlights areas of greatest need for research. However, relative returns anticipated from specific research areas are not identified here. Rather, it is envisaged that a broad-ranging multidisciplinary approach will be necessary to achieve significant progress. For example, advances in science and engineering are, in isolation, of limited value. They may only become practice to the extent that community acceptance, economic incentives and government regulation allow. Conversely, community acceptance of the need for water recycling can achieve little without the means to effectively treat water to standards suitable for reuse. A multidisciplinary integrated approach to research may in itself lead to improved integration of water management. The structure of institutions in Australia lends itself to complex administration of water recycling proposals by governments. Institutional arrangements prevent the integrated management of water as different authorities are responsible for each of the varying aspects of the water cycle. Consequently research in water management is segregated and thus impeded by the structure of research institutions along the arrangements of government. One approach to overcoming some of these difficulties would be to promote and foster

increased collaboration between disciplines and institutions. Collaboration should involve an optimal distribution of tasks and responsibilities along with rapid and broad dissemination of research findings. Increased multidisciplinary collaboration may be encouraged as a component to be considered in research funding awards. More directly, management and regulation should be undertaken in a manner not delineated by the varying interests of local, state and federal governments or their associated institutions. The current multitude of authorities responsible for catchment, water treatment and distribution, sewage treatment and discharge, may be better structured as a single large authority responsible for the whole of the water cycle. This would facilitate an understanding that terms such as "drinking water" and "wastewater" refer only to temporary stages of a continuing cycle. Similarly, state and national research organisations should be more closely integrated. These organisations could be structured in a manner that better reflects the continuum of the water cycle rather than a segregation into largely artificial compartments. Integrated water management would naturally lead to more transparent costing and pricing structures for water. The inclusion of costs such as catchment management and sewage treatment in the delivery of water to consumers would be facilitated. This would enable a more realistic comparison of the costs of recycled water and fresh water supplies. Likewise, community education will be most effectively achieved by instilling an understanding of the total water cycle. Education programs that enable an appreciation of a broad approach to water management will aid in the quest for community acceptance of the need and advantages of water recycling. Through a commitment to research, consultation and collaboration, Australia may be confident of overcoming impediments currently posed to large-scale water recycling. Successfully implemented, a multidisciplined, integrated approach to water management and research offers promising returns for the sustainable management of our natural water resources far into the future.

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The Authors Stuart Khan is a Research Fellow, Environmental Engineering, University of Wollongong, skhan@uow.edu.au;

Andrea Schäfer is a Senior Lecturer, Environmental Engineering, University of Wollongong, a.schafer@uow.edu.au;

Paul Sherman is a Principal Scientist, Water Sciences Unit, Environmental Sciences Division, Environmental Protection Agency (Queensland), paul.sherman@epa.qld.gov.au

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